WHITEPAPER

INCREASING THE LIFESPAN AND RELIABILITY OF ELECTRONIC COMPONENTS

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SUMMARY

An insider's guide to maintaining the consistent temperatures in electrical enclosures that are necessary to protect heat-sensitive electronic components—improving operating efficiency and extending lifespan.

INTRODUCTION

Heat is both a by-product and one of the greatest enemies of electrical and electronic components. If not dissipated, this heat has the potential to cause early failures and malfunctions. Components commonly packaged in electrical enclosures, computer server racks, and other product compartments are the vital controls for drives and displays used in many industries, including:

- **Telecommunications**
- **Industrial Automation**
- **Medical Device Technology**
- **Transportation & Mass Transit**
- **Self-Service Kiosks & ATMs**
- **Petro-Chemical**
- **Steel Manufacturing & Forming**
- **HVAC**
- **Food & Beverage Processing**
- **Machine Tools**
- **Wastewater Treatment**
- **Water Purification**
- **Security Detection & Imaging**
- **Robotics & Industrial Automation**
- **Paper Manufacturing**
- **Elevator Controls**

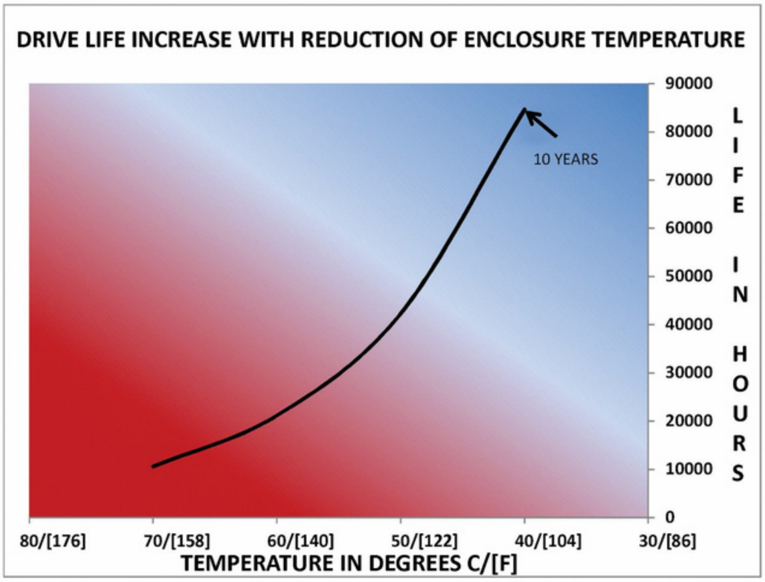
The primary purpose of these electrical enclosures is to provide protection and safety for the components they house. If an enclosure is properly cooled, the components within can have a long and useful life. Without proper cooling, however, the components in these enclosures can be subject to damaging heat, shortening their longevity and reliability.

Although individual manufacturer's specifications vary, the majority of electrical distribution and control equipment is designed to operate properly and achieve normal life expectancy under ambient air conditions ranging from 40°-50°C [104°-122°F]. The table below indicates the maximum operating temperatures for specific devices. (It is generally accepted that operating temperatures above this range reduce life expectancy: Every ten-degree rise in temperature shortens the average reliability of electrical/electronic components by 50%.)

Device	Maximum Recommended Air Temperatures for Operation	Cautionary Notes
Variable Frequency Drives	40°C [104°F]	Operation above this temperature typically requires de-rating a larger drive or risking premature failure.
Variable Frequency Drives w/ External Heat Sinks	50°C [122°F]	Operation above this temperature typically requires de-rating a larger drive or risking premature failure.
Human Machine Interface (HMI), Touch Screens & Flat Screen Displays	50°-60°C [122°-140°F]	Manufacturers of HMI specify a maximum operating temperature for their products. A few smaller devices are available that operate as high as 70°C (158°F).
High Definition (HD) Televisions	40°-50°C [104°-122°F]	32°C (90°F) is recommended for normal life expectancy.
Programmable Logic Controls (PLC)	50°-80°C [122°-176°F]	Most devices are not certified to function properly beyond their maximum operating temperatures.
Computers & Server Racks	Internal air temp. 40°C [104°F] With cooling fans 55°C [130°F]	In a loaded PC with standard cooling, operating temperatures can easily exceed the limits. The result can be memory errors, hard disk read-write errors, faulty video, and other problems not typically recognized as heat related. Nearly all server racks require cooling.

Examples of components typically found in electrical enclosures.

Based on the information provided in the table above, it is clear that thermal management is advantageous. Reducing the operating temperatures within electrical enclosures is an effective way to increase life expectancy and system reliability. If an enclosure is properly cooled, the cost associated with that cooling can be recovered over the life of the equipment. The graph below, "Drive Life Increase with Reduction of Enclosure Temperature" illustrates the benefits of increased longevity when a drive enclosure is cooled properly. This is based on typical drives having a 40°C [104°F] maximum recommended environmental temperature.



THE SOURCES OF HEAT

The primary source of heat production in an electrical enclosure is from the working components. Devices that transmit motive power have voltage drop or efficiency losses that are converted into heat. In the case of electronics or microprocessors, nearly all of their power is converted into heat. The means for calculating and estimating this heat generation are available from enclosure cooling manufacturers in the form of spreadsheets or calculators. Heat gain or loss is expressed in watts or BTUs (British Thermal Units). These units of heat are converted as follows:

- **Watts = BTU/hour ÷ 3.414**
- **BTU/hour = Watts x 3.414**

This internal heat load is one source that will cause the internal enclosure temperature to rise to unacceptable levels if it is not removed.

AMBIENT AIR

Ambient air, which is the air outside the enclosure, can also be a potential source of heat gain. The ambient air may be cool enough to allow the enclosure to dissipate heat, however, in many cases, ambient air may be so hot that it adds to the heat load.

SOLAR LOAD

When enclosures located outdoors are exposed to the sun, heat will be transferred to the inside of the enclosure. This is known as solar load or solar gain. (The effects of solar load can be significant; an automobile parked outdoors on a sunny day is a prime example.) Thermal insulation, white reflective paint finishes, and a roof or sun shield will often help to offset solar load. Some enclosures are double-walled for this purpose; however, this tends to be very costly.

HUMIDITY & AIR INFILTRATION

Outside air entering an electrical enclosure carries both heat and humidity. High relative humidity in the air potentially increases the heat content; in most cases, it is best to seal the enclosure to limit this effect. Condensing water vapor or the formation of dew from high humidity, particularly in outdoor enclosures, will damage the electrical and electronic contents of an enclosure. It is best to seal up enclosures and feed conduits completely to avoid this type of heat gain and the effects of humidity.

REMOVING THE HEAT

Heat transfer by natural convection is the simplest and most common method of cooling electronics. Relying entirely on hot air rising, however, is generally not sufficient to safely cool sensitive electronics and electrical power transmitting components. Often natural convection is used in conjunction with a heat sink to keep electronics cool. An electronic component mounted on a heat sink helps cool the electronics by dissipating heat into the air. Such passive thermal management solutions are found in consumer electronics, appliances, and systems where enclosures or compartments are not subject to sufficient heat gain to cause a significant heat build-up. Environmental testing is performed for agency-listed products and mass-produced products to be sure passive heat dissipation will be effective.

BLOWERS, FANS, FAN TRAYS, & MOTORIZED IMPELLERS

Blowers

Packaged Blowers

Blowers, fans, motorized impellers, and fan trays are open-loop cooling systems that can be used when the surrounding air can be passed over the heat-producing components and exhausted from the enclosure. Fans usually have some type of air filtration; even applications in the cleanest environments should have minimal protection from drawing airborne particulate into the enclosure. Packaged blowers can be used in enclosures to cool in high static pressure conditions, and motorized impellers, as well as fan trays, can be used to cool hotspots either alone or in conjunction with other cooling systems.

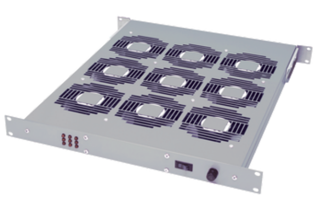
There are two airflow options when open-loop cooling is used on an enclosure: one is to pressurize the enclosure, and the other is to create a vacuum. Of the two options, pressurizing is preferred because it will utilize all louvers, cracks, and openings as part of the exhaust flow, rather than pulling air and possibly dirt in through them.

Open-loop systems are limited in that they can only cool to a certain point above the ambient temperature. In applications where the ambient temperature is too high, or the airflow necessary to provide the required amount of cooling becomes too high, an air conditioner, water-to-air heat exchanger, or air-to-air heat exchanger is necessary.

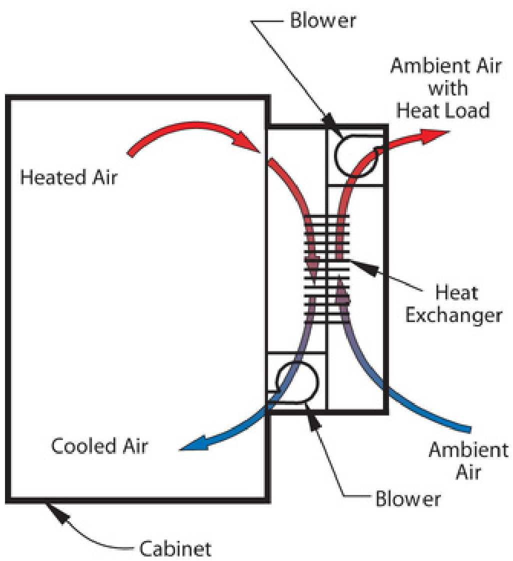
Impeller Blowers

Fans

Fan Tray



HEAT EXCHANGERS



Air-to-Air Heat Exchanger

In an air-to-air heat exchanger, heat is removed from the air surrounding components by a specially designed heat transfer element before being routed back into the enclosure.

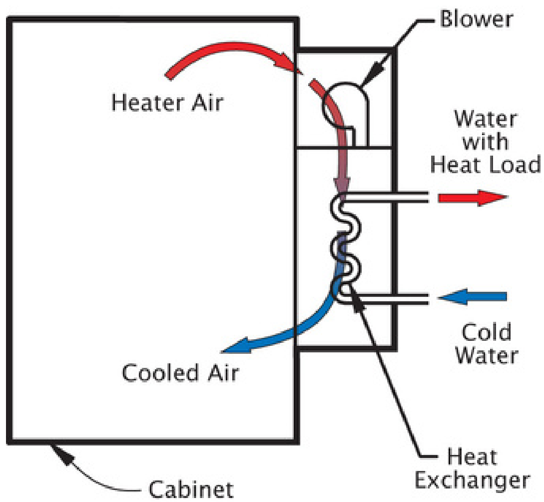
Air-to-air heat exchangers utilize closed-loop cooling. A closed-loop system will cool an enclosure without introducing outside air, which may be too hot or dirty. Heat exchangers are a good choice when it is necessary to remove heat from an enclosure while keeping out the surrounding ambient air.

Air-to-air heat exchangers operate by means of two separate airflows which pass through a convoluted metal foil element. Enclosure heat is transferred from one side to the other through the element and exhausted to the outside.

Heat exchangers have a lower initial cost and are generally less expensive to maintain than air conditioners. However, heat exchangers share the same limitations as open-loop cooling systems.

Water-to-air heat exchangers provide cooling in a closed-loop system where a reliable source of clean, cool, or chilled water is available. Models are available that are designed primarily for use in harsh environments and feature cooling capacities in excess of air-to-air heat exchangers. They are particularly useful in highly contaminated environments that would require frequent cleaning or changing of ambient air filters or frequent cleaning of the heat exchanger core.

Water-to-air heat exchangers provide greater heat transfer performance than air-to-air heat exchangers, in a compact package.



Water-to-Air Heat Exchanger

A water-to-air heat exchanger works by transferring heat of internal air to circulating water, resulting in cooler air which is recirculated throughout the equipment enclosure.

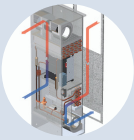
AIR CONDITIONERS

Closed-Loop Cooling
Closed-loop air conditioners maintain the optimal temperature within an enclosure while keeping out warmer ambient air, humidity, dust, dirt, and other airborne contaminants.

Special-purpose enclosure air conditioners are recommended where high heat transfer and closed-loop cooling are required. Unlike their comfort cooling counterparts, special-purpose air conditioners are closed-loop systems designed for use in higher ambient conditions.

Typical air conditioners have refrigerant-charged compressors that are controlled by a thermostat to limit electrical enclosure temperatures while saving energy between cycles. Initial investment and operating costs are higher than those of the previously referenced cooling systems.

Air conditioners should be sized for a maximum allowable temperature from which the BTU/H is determined. The maximum enclosure air temperature should be limited to the lowest maximum operating temperature for each specific device. Usually, the most susceptible devices contained within electrical enclosures are variable frequency drives (VFDs) and computers.



Watch our Closed-Loop Cooling video at kooltronic.com/closed-loop-cooling

SYSTEM DESIGN & ECONOMIC CONSIDERATIONS

It is important to think about cooling in the early stages of the design process, whether designing a new system or retrofitting an existing system. If you configure your enclosure to run cool and dry from the beginning, you can enjoy reliable system operation and avoid the cost and frustration of system failure.

AVOIDING CONDENSATION

In order to avoid a build-up of condensation, internal enclosure heaters are an important accessory to consider when designing a cooling system for an application.

In outdoor applications, during the night or off-peak hours, the internal enclosure temperature may drop below the dew point. This causes condensation to accumulate on sensitive electronics and electrical contact surfaces, leading to corrosion and ultimate failure. To prevent this problem, an internal heater should be used to maintain the temperature of the enclosure. Heaters are commonly incorporated into air conditioners and are also available as individual devices.

Fan Heaters

NEMA ENCLOSURE RATINGS

NEMA (National Electrical Manufacturers Association) enclosure ratings are placed on enclosure cooling units and electrical enclosures to designate the environmental hazard from which the contents are being protected. NEMA defines the standards for different levels of protection of electronics enclosures.

Typical examples of NEMA ratings include NEMA 12 for indoor use, protection from dust and dripping liquids; NEMA 3R for outdoor use and rain-proof applications; and NEMA 4X for indoor/outdoor use to provide protection from wash-down and corrosive environments. The NEMA rating on an air conditioner should be matched to the NEMA rating on an enclosure being cooled.

Outdoor Enclosure with AC

Environments	NEMA 1	NEMA 12	NEMA 3R	NEMA 4	NEMA 4X
Indoor use only	✓	✓			
Indoor & outdoor use			✓	✓	✓
Falling liquids & light splashing		✓	✓	✓	✓
Non-hazardous dust, lint, fibers		✓		✓	✓
Washdowns & splashing water				✓	✓
Oil & coolant seepage		✓	✓	✓	✓
Corrosive agents					✓
Hazardous Location (Class I, Division 1 & 2)				✓	✓

Environmental conditions and associated NEMA ratings for enclosure cooling products.

INVESTMENT IN ENCLOSURE COOLING YIELDS HIGH RETURN

The installation costs of an enclosure housing a variable frequency drive and associated controls, together with the cooling system designed to cool the application can range from under $50,000 to over $100,000. This application could be part of a manufacturing process or service generating considerable revenues. The cost of installing an enclosure cooling system designed for a specific application is very low when compared to the cost of the overall system, ranging from 2%-4% of the entire equipment cost. This low-cost percentage per application is also true of large signage, kiosks, and computer servers.

The economic and safety-related consequences of improper heat dissipation for systems used in critical infrastructure as well as other possible service interruptions should be considered at the design stage. Lost revenue due to heat-related failures can quickly justify the expense for enclosure cooling.

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